

Towards integration of methodologies for assessing and promoting the societal embedding of energy innovations

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Abstract

The necessity for system innovation is well acknowledged, but inducing system change proves to be very difficult. Three approaches have been developed for analysing and supporting radical innovations: Socrobust, Create Acceptance and Strategic Niche Management. This paper gives an overview of these complementary approaches and their theoretical background. The paper also identifies several potential contributions for social scientists to contribute to energy research and the implementation of more sustainable alternatives.

1. Introduction: transitions and long-term development patterns

It is obvious that our energy system, based on fossil fuels, is not sustainable in the long term. Although the necessity for system innovation – i.e. a transition to a more sustainable system – is generally acknowledged and several alternative technologies are available (renewables), it proves to be very difficult to change the incumbent system. Literature from Innovations Studies and from the Science and Technology Studies (STS) field suggests that inducing system change proves difficult for all (potential) radical innovations, but in the case of the energy system this is in particular hard, because it involves collective goods and large vested interests in infrastructures and energy plants.

To understand the difficulties of promising technologies to breakthrough or, complementary, to explain the stability of the dominant system, STS and innovation scholars have developed a Multi-Level Perspective (MLP) on innovations. The essential point of this MLP is that developments can only be understood as the outcome of multiple interactions and co-evolutionary processes between the various levels (Rip and Kemp, 1998; Geels 2002).

The multi-level perspective distinguishes three analytical levels, a micro of niches, a meso of socio-technical regimes and the macro-level of the socio-technical landscape. The central level in understanding the resistance to structural change is the meso-level or the *socio-technical regime*. This level accounts for the stability of the existing technical system. The regime consists of three interlinked elements: (1) a network of actors and social groups, which develops over time; (2) the set of formal and informal rules that guide the activities of actors who reproduce and maintain the elements of the socio-technical system and (3) the material and technical elements (Geels 2004). For example, the dominant actors in the energy regime are utilities, oil companies, the government, large industrial users and households. The micro-level is formed by *technological and market niches* that form the locus for the emergence of new technologies (Schot, 1998; Kemp *et al.*, 1998). Such niches are formed by

relatively small networks of actors who are willing to invest time and resources in the development of novelties. The networks are usually heterogeneous, made up of universities, public authorities, entrepreneurial firms, but also large firms. Niches act as ‘incubation rooms’ for radical novelties, shielding them from mainstream market selection. New technologies need such protection, because they have initially low performance and high price. Much work is needed to improve new technologies, leading to a stable and robust design. Technological niches then can enter the market. The macro-level is the *socio-technical landscape*, forming an exogenous environment that influences developments in niches and regimes. The metaphor ‘landscape’ is used because of the literal connotation of relative ‘hardness’ and to include the material aspect of society, e.g. the material and spatial arrangements of cities, factories, highways, and electricity infrastructures. Niches and regimes develop against the background of external developments in this landscape, but the landscape is beyond the direct influence of actors, and cannot be changed at will. Material environments, shared cultural beliefs, symbols and values are hard to deviate from. The socio-technical landscape therefore usually changes slowly, e.g. through demographic, macro-economics and cultural changes (Geels 2004). Fluctuations in global oil prices are an example of such a landscape developments with a major impact on the incumbent energy regime and the more sustainable alternatives.

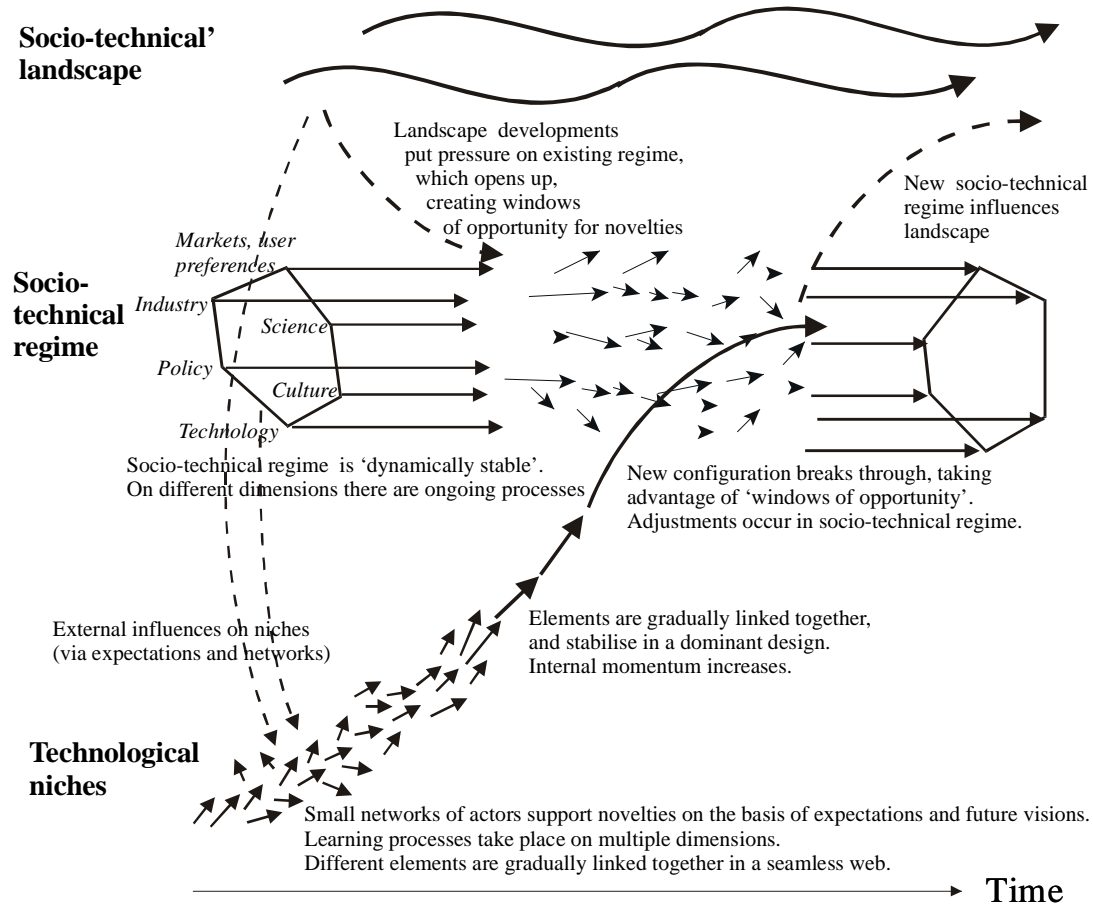


Figure 1. Dynamic representation of the three levels in the multi-level perspective (Geels, 2005).

In the early MLP literature the main route to a regime shift is by substitution. A technological niche develops into a small market niche by processes of up scaling or branching to new application domains and it gradually takes over from the incumbent regime. Of course landscape pressure and regime instability creating ‘windows of

opportunities' are essential, but still this process can be represented by the well-known S-curve. However, in particular for systemic technologies, e.g. the electricity system or infrastructural technologies, a substitution route is not a very obvious one, because of the complexity and the interrelatedness of the components of the system. Geels and Schot argue therefore that there are more transition routes or pathways, including a transformation, a reconfiguration and a de-alignment/re-alignment route. These pathways differ in combinations of timing (of landscape pressures) and nature of the multi-level interactions, e.g. on the role of regime actors and outsiders or between economic and social mechanisms (Geels and Schot, forthcoming).

From a policy perspective there are several options to encourage the development of sustainable technologies. One way is to increase pressure on the regime, e.g. technology forcing by strict environmental legislation, or by using the opportunities offered by more general trends, a modulation approach. Another way is to stimulate the creation of niches by supporting the development of new technological innovations. This is the most common strategy, but unfortunately these efforts are characterised in general by a strong technology push approach. This results in a large variety of promising technological options, but most technologies never fulfil their promise because not enough attention is paid to the implementation process and to the societal embedding of new technologies. Experimenting with innovations in real life circumstances offers a perspective to tackle these problems. This is one of the areas where the ASRELEO-initiative can offer a significant contribution and is also the focus of this paper.

2. Transitions and the role of experiments

Innovation studies often focus either on the R&D phase or on the diffusion phase. However, there is also an important phase in the innovation trajectory when the innovations leave the laboratory but are not yet ready for entering the market. This is the phase of societal experiments. These experiments have to provide insight in the potential of an innovation both in terms of performance and functionality. From an evolutionary perspective societal experiments form a nexus between the variation and selection environment. A nexus is a deliberately created link for learning about the potential of an innovation by exposing it to a more or less controlled selection market environment. It allows users, policy makers or special-interest groups to give feedback to technology developers (Schot 1992). Societal experiments therefore are about learning and creating support for a new innovation. Often innovations fail because of a neglect of this phase or because an exclusive focus on the technological aspects. This phase therefore is crucial for a successful implementation. This applies in particular for systemic technologies, that have a very long trajectory or incubation period, e.g. most energy technologies.

According to Hoogma there are several types of experiments, displaying increasing knowledge about the innovation (Hoogma 2000):

- Explorative experiments; in this early phase learning about potential and impacts of an innovation takes central stage.
- Pilot experiments. The focus here is on raising more general awareness about applications, feasibility and acceptability by testing in other locations/environments
- Demonstration projects. The essential point is here to demonstrate to potential adopters what the innovation has to offer
- Replication or dissemination experiments. This type of experiments aims at the implementation/diffusion of the innovation by replicating successful earlier experiments (Hoogma 2000).

Recent work on the development of niches shows a change in focus from single to multiple projects or experiments (Geels and Raven 2006). This work stresses the importance of a distinction between the local level of concrete projects or experiments and a more global niche-level. The local level consists of the actors that are directly involved in experiment, while the niche level is carried by an emerging field or community. Another characterisation of this distinction between the local and d global in cognitive terms distinguishes between local knowledge with variability (skills, hands-on-experiences) and more global, abstract, generic knowledge that is shared within a community. The transformation of local outcomes into generic lessons and knowledge does not occur automatically, but requires dedicated ‘aggregation activities’ (Geels and Raven 2006; Deuten 2003). The niche itself develops against the background of one or multiple regimes. Raven (2005) demonstrates the importance of niche-regime interactions for the development of the biomass niche in the Netherlands.

A related aspect concerns the societal embedding of (potential) radical innovations. The difficulty to change the incumbent system through (potential) radical innovations has to do with a recurrent assumption held by technology developers and policy makers. These often assume that having secured the techno-economic dimension of innovations would be enough for its adoption and diffusion. In practice many energy projects (including wind, bio energy, and hydrogen) face severe resistance from various stakeholders including actors that are not direct users of the technology. This phenomenon classically labelled as resistance to change has been extensively studied by scholars from Science and Technology studies (STS) and shown to be closely associated with the societal transformation/impact often associated with the technologies, and the sometimes conflicting visions about their consequences and desirable path to follow among different stakeholders. Cases in which such conflicts are emerging have been shown to be conducive to important management problems, in particular when conflicting visions are neglected in the early phase of innovation. The approaches presented here will also address this issue.

3. Approaches to system innovation through radical innovation

This section discusses three approaches in which socio-technical experiments play an important role. The following table summarizes the main differences and complementarities. Each approach will be discussed more in depth in the following sub sections.

	Socrobust	Create Acceptance	SNM
Type of tool	consultancy tool	consultancy tool	research tool consultancy tool
Type of activity	ex post evaluation and monitoring of project management	ex post evaluation, monitoring ex ante strategic market entry societal acceptance management	mainly ex post evaluation
Unit of Analysis	R&D project single innovation	pilot project program / innovative system	niches (a series of projects)
Type of innovation	technological and social	technological (and	Technological (and

		social)	policy)
Phase of innovation	R&D	demonstration	demonstration
Targeted users	Innovators project managers	innovators project managers program managers all relevant stakeholders	programme managers innovation researchers
Aim	reflective development practice	diffusion of innovation	reflective development practice
Method/instrument	vision forming learning about non-technological issues extending network enhancing network alignment	vision forming learning about non-technological issues extending network enhancing network alignment	articulation of expectations learning about non-technological issues extending network enhancing network alignment enhancing (governmental) protection
Theoretical foundation	STS, in particular Actor-Network theories Project management literature	STS Transition theories	Evolutionary theories Sociology of technology Constructive technology Assessment Transition theories

3.1 Socrobust: an introduction

Socrobust is a method developed in 2002 by STS researchers as a support tool for technology developers and project managers dealing with breakthrough innovations – i.e. innovations that potentially raise problems of acceptance as they change existing practices in society (Laredo et al., 2002). These STS researchers had observed that many technological projects fail due to inappropriate consideration of the societal diffusion side of innovations. Socrobust was composed as a tool-kit and a protocol for interaction with project managers to help these managers anticipate future consumers and societal reactions to the innovation. 20 years of STS literature was incorporated into an exploratory method for anticipating future stakeholders reactions to innovation. It was then first tested against 8 European small business innovation projects in areas such as micro-CHP and telemedicine. Socrobust is a tool that is developed with a *single* stakeholder perspective: the innovator, that aims to allow for a better management of the societal dimension of technological projects. The instrument consists of four steps and several instruments that will be discussed briefly below. All information about these steps is taken from (Jolivet, E. Mourik, R.M. et al., 2006).

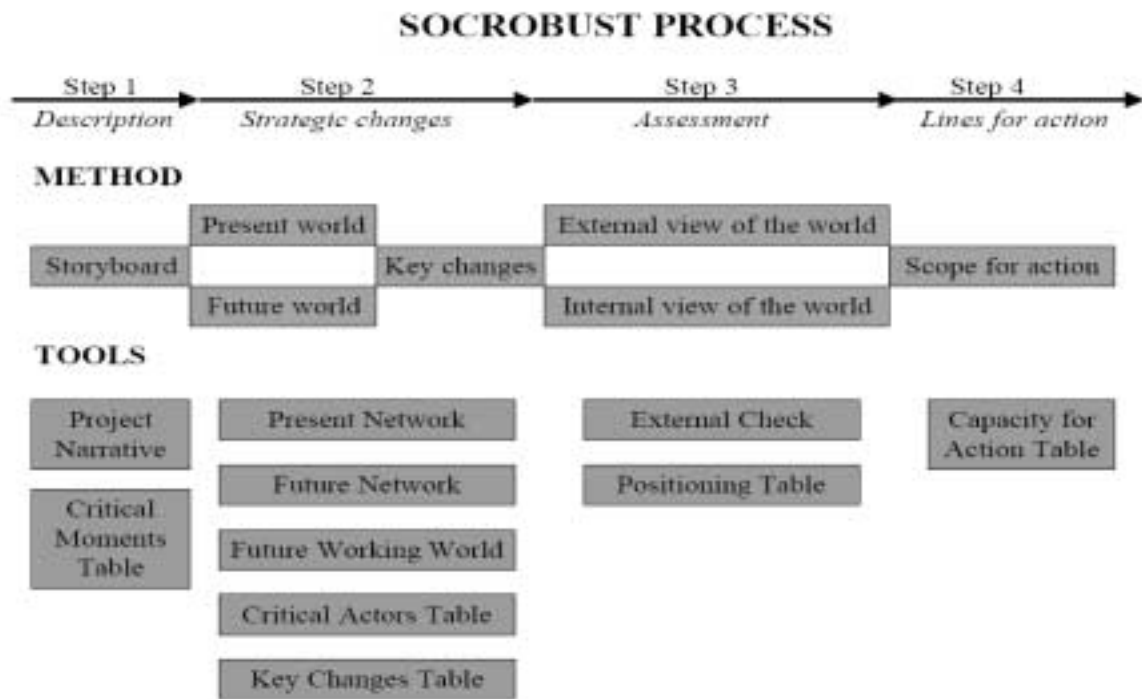


Figure 2: the Socrobust process. Source: (Laredo et al., 2002)

3.1.1 Step 1: Project story

The first step focuses on identifying the technological, economic actors and factors involved in the project: the Techno-Economic Network (TEN) as a basis for assessing the project's current social robustness. Two instruments are used for this purpose. The narrative and the critical moments table.

The narrative is a chronological story starting with the start of the project until the present and the identification of the critical moments that occurred which led to a "shift" in orientation and their consequences for future steps. What many narratives showed was that innovation projects have long and changing journeys and can keep something of the original while changing a large part of their constituents. The narrative is a written text, but can also be visualised in a flow diagram. The critical moments table identifies key moments, which modified the aim, tasks and path of the project, sometimes to the effect that the new path becomes irreversible. These critical moments occur i.e. due to new technical opportunities; problems in the internal alignment of partners; and learning through demonstration and trial activities. As such, the critical moment table highlights the presence of a number of shifts that were not expected in advance and that superpose themselves on the "normal" expected stages of the project.

3.1.2 Step 2: Project unfolding

This second steps first aims at identifying the present TEN network in which the project is involved. The present network makes the linkages visible within and between the project and its environment in at least four domains: regulation, science, users and producers. The stakeholders involved in the current configuration of the project are identified and visualised in a key actors table that characterizes the stakeholders in terms of their centrality in, involvement in, motivation to join the

project and alignment towards the project manager. This second step also identifies the TEN that the innovator identifies as desirable for the future diffusion of the innovation. It is a description of how users, suppliers and regulation bodies relate to each other; what rules and convention govern their interactions; the institutional infrastructure and the practices needed for the emergence and adoption of the innovation (i.e. entry in the market). The comparison between the present and the future TEN identifies necessary actions and the boundaries to room for action to shift from the present situation to the desired future situation.

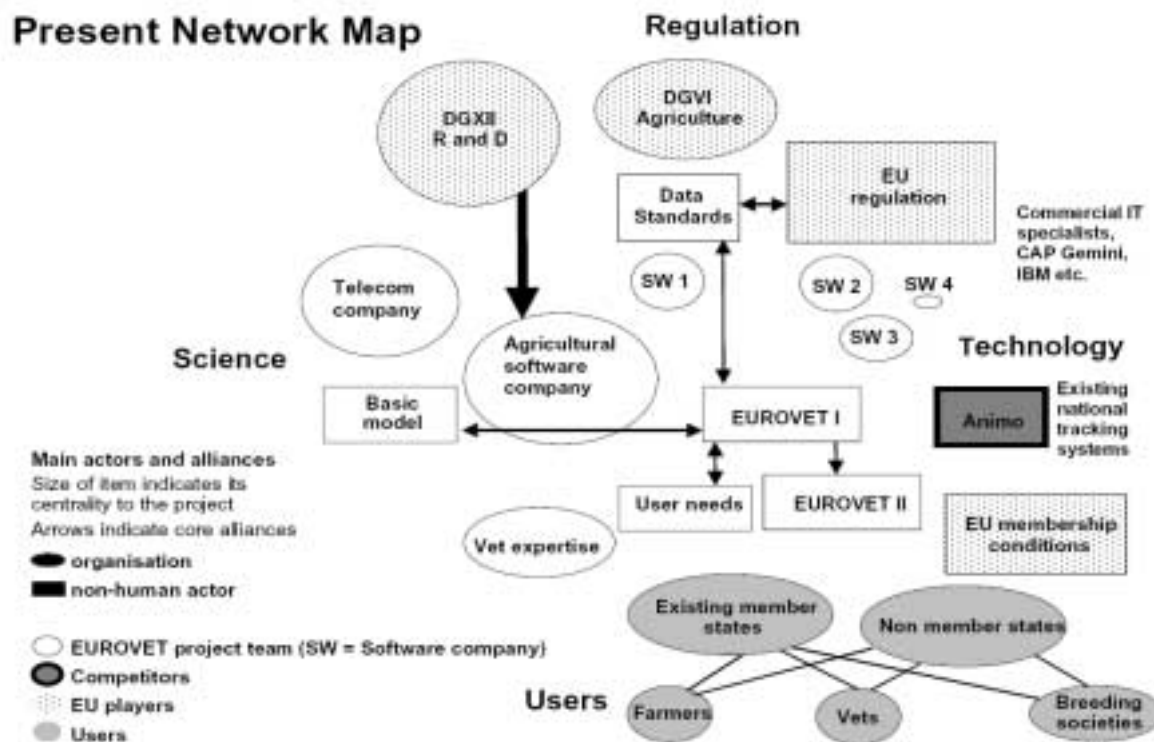


Figure 5: An example of the present TEN. Source: (Laredo et al., 2002)

3.1.3 Step 3: Societal robustness assessment

The third step puts the present and future TEN in perspective and identifies alternatives to the desired path and the consequences for the project if these alternatives would actually enter the market. By means of an "external check" possible alternative developments and the consistency of the innovator's assumptions are checked through a search on the web, in newspapers and other relevant documents. With the outcome of this external check the project can be positioned with respect to these alternatives and with respect to potential opponents and allies.

3.1.4 Step 4: consultant activity

The last step aims at reflecting on the project visions, objectives and implementation with the lessons learned during the Socrobust process in mind. The result is the development of a short term action plan. The consultant identifies recommendations for action. Possible actions are focused on enrolment of actors to extend and thus strengthen the current network and actions are focused on aligning these actors to maximise the mutual influence and relation between actors and their actions. The consultant also identifies the place, time and room for these actions.

To conclude, Socrobust is a consultancy tool that aims to help project managers, innovators to evaluate and monitor the potential societal robustness of innovations in an R&D phase, by anticipating possible present and future societal developments and reactions. The actual market entry phase was not the target of Socrobust. The Socrobust tool was further not developed to work with more than one innovation, and the tool was certainly not developed to work with other stakeholders than the project manager or innovator.

3.2 Create Acceptance

After the Socrobust project ended, ECN continued to test and evaluate the Socrobust tool during a second row of experiments performed internally at ECN. Although the general orientation of the Socrobust method was confirmed, a number of lines of improvements were identified in the process, and tools were adapted for better efficiency. Still some major issues remained to be solved. First ECN wanted Socrobust not only to function as an evaluation or monitoring tool but also as a tool that could actively promote societal acceptance of innovations. In addition, ECN felt that the tool should be extended to be not only useful as a consultancy tool for technology managers or single project managers, but that could also be used by the multiple and varied stakeholders that are involved around new innovations. Therefore, in cooperation with 9 European institutes, a new project was established: the European research project 'Create Acceptance'. The main objective of this Create Acceptance project is to transform the existing Socrobust method into a *multi-stakeholder* methodology that not only includes the innovator's vision, but also a variety of visions and perceptions of other stakeholders. The new tool will be tested and applied in five renewable energy projects in 2007.

The Create Acceptance tool will thus be a consultancy tool that targets the market entry phase of a single innovation or an innovative system, aims to enhance the success of this market entry and target not only the project manager but focus more on the alignment of all relevant stakeholders internal and external to the project.

3.3 Strategic Niche Management

In order to tackle the dilemma of breakthrough, researchers from the STS-field have developed the approach of Strategic Niche Management (SNM). SNM is defined as "a deliberate attempt to make visible and productive the co-development of technological options, use, policy measures and sustainability by the creation, development and controlled break-down of societal experiments for promising technologies" (Weber et al. 1999). SNM particularly builds upon insights from evolutionary theories on technical change (in particular evolutionary economics) and on Technology Assessment approaches. Later SNM publications introduced insights from sociology of technology field (Raven, 2005; Geels and Raven, 2006). This section gives a brief overview of SNM.

SNM originally emerged from the observation that, in particular in the transport sector, many innovations with (potentially) improved environmental characteristics fail to become commercially successful. The car industry, for example, has investigated and experimented with several options in the past (in particular, battery-powered vehicles), but never achieved large commercial exploitation (Hoogma et. al, 2002). SNM has a two track explanation for the lack of success of environmental innovations.

First, many authors point to the lock-in of existing energy and transport systems and their resistance to change (Cowan and Hultén, 1996; Jacobsson and

Johnson, 2000; Unruh, 2000). Systems are locked in through technological, institutional and social path dependency, resulting in a variety of barriers for new innovations such as the lack of a fuel infrastructure, the lack of clear government regulations or hard competition with a network of incumbent actors that do not support the innovation. Incumbent firms have developed routines and tend to reproduce those activities that they found successful in the past. These firms are therefore blind for innovations that do not fit their scope, such as radical environmental innovations. Moreover, dominant designs continue to improve. The internal combustion engine, for example, has been continuously improved over the past decades in terms of environmental and technical performance, making it harder for alternatives to breakthrough. On the other hand, existing regimes may also face problems (e.g. because of public pressure to improve environmental performance), creating windows of opportunities for alternatives. So, dynamics in established regimes are an important explanation for understanding success and failure of environmental innovations and SNM explicitly includes these dynamics as explanatory variable (Raven, 2005, 2006).

Second, new technologies often suffer from limited technological and economic performance compared to the dominant design, which has already profited from decades of dedicated research and development. Therefore, SNM argues that because new technologies lack a competitive advantage, they need nurturing and further improvement. One way of doing this is through experimenting in various niche markets (Schot, 1992; Levinthal, 1998).

SNM scholars argue that niche markets such as special geographical locations or application domains can act as stepping stones for innovations. Niche markets are distinct selection environments, where users have different requirements than in mainstream markets. Photovoltaic cells, for example, were first applied in space travelling, where costs of energy production were less important. Also firms might use niche markets as a strategy to 'test' the innovation in different market settings – a strategy which has been nicely coined with the term 'probing and learning' (Lynn, Morone and Paulson, 1996). For sustainable technologies, however, often no clear markets exist. Sustainable technologies require markets to be created in a process of *co-evolution* of market and technology. This can be done by temporarily protecting the innovation from too harsh selection, for example with investment grants, tax exemptions or other forms of 'protection'. So a *protected space* (or technological niche) is created which can serve as a test bed for further improvement (Kemp, Schot and Hoogma, 1998).

Several scholars have investigated more precisely how an experimental introduction of sustainable innovations in niche markets can benefit the diffusion of the innovation. The level of analysis in this literature is often (a series of) projects such as pilot plants and demonstration plants, covering a substantial number of projects over periods up to thirty years. These scholars tend to ask the question why a certain niche trajectory was a success or a failure. They seek the answer in investigating three internal processes that constitute the nature of development of a niche technology.

The first process is *voicing and shaping of expectations*: firms, users, policymakers, entrepreneurs and other relevant actors participate in projects on the basis of expectations. Articulating expectations are important to attract attention and resources as well as new actors. And expectations also provide direction to development: they act as cognitive frames making choices in the design process.¹ The

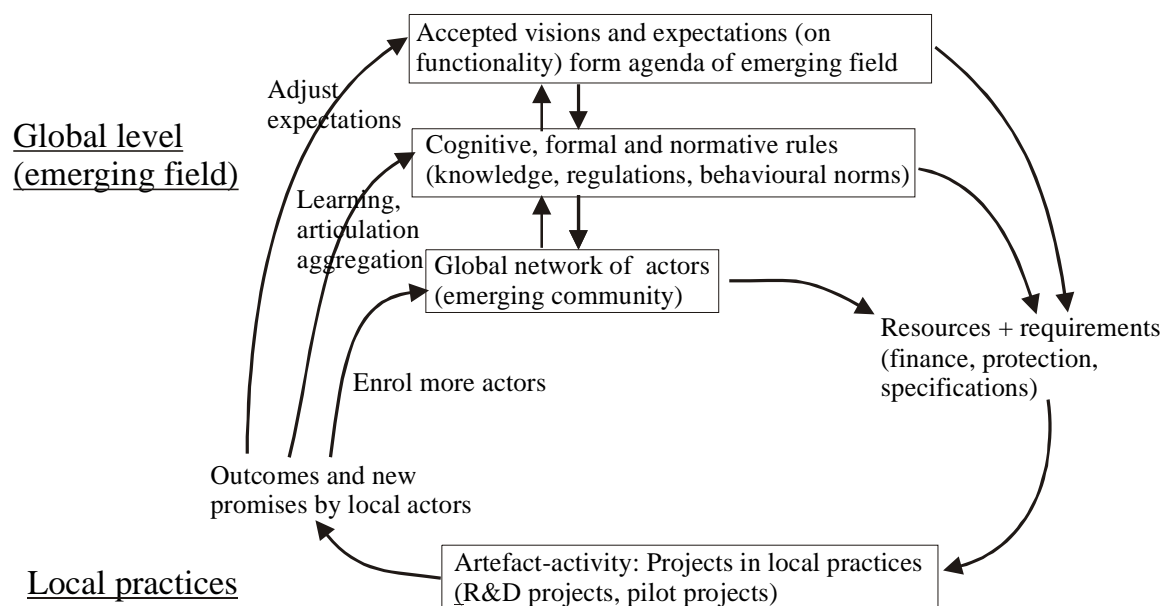
¹ The process of expectations guiding design choices follows a 'promise-requirement cycle' (Van Lente, 1993). When a new technological opportunity emerges, its advocates formulate promises about future performance and functionality to attract attention from sponsors. If these promises are accepted, they

process of voicing and shaping of expectations is considered to be good when a) an increasing number of participants share the same expectations (expectations are converging), and b) the expectations are based on tangible results from experiments.

The second process is the *building of social networks*. In particular in early phases of an innovation's life cycle, the social network is still very fragile. Experimentation in niche markets can bring new actors together and make new social networks emerge. Building of social networks is considered good when a) the network is broad (including incumbent and new firms, users, policy makers, scientists, and other relevant actors), and b) when alignment within the network is facilitated through regular interactions between the actors.

A good *learning process*, the third process identified in SNM, is widely recognized as crucial for successful innovation. It enables adjustment of the technology and/or societal embedding to increase chances on successful diffusion. A good learning process is a) broad – focusing not only on techno-economic optimisation, but also on alignment between the technical (e.g. technical design, infrastructure) and the social (e.g. user preferences, regulation and cultural meaning) – and b) is reflexive – there is attention for questioning underlying assumptions such as social values, and the willingness to change course if the technology does not match these assumptions.

Dynamic interactions between these three processes form the basis within SNM for understanding success and failure of innovation processes (Geels and Raven, 2006). Actors, embedded in networks, are willing to invest resources (money, people) in projects, if they have a shared, positive expectation of a new technology. This shared expectation, together with shared cognitive rules, also provides direction to the projects. Projects, carried by local networks, provide space for local activities. The outcomes give rise to learning processes, which may be aggregated into generic lessons and rules. Outcomes are also used to adjust previous expectations and enrol more actors to expand the social network (see Figure 1).



are translated into a shared expectation or agenda for an emerging field. The expectation is then translated into goals, specifications, requirements and task divisions, for which projects are developed. Sponsors make money and other resources available for these projects, thus creating a protected space where search and development activities may take place. When the projects end, usually after a couple of years, outcomes are assessed and new promises are formulated.

Figure 12. The dynamics of niche development trajectories

The SNM framework has been applied to various sustainable technologies such as wind turbines (Kemp, Rip and Schot, 2001), battery powered vehicles (Hoogma et. al., 2002), fuel cell vehicles (Lane, 2002), photovoltaic cells (Van Mierlo, 2002), biogas plants (Raven, 2005) and biomass co-firing (Raven, 2005, 2006). The focus in these studies was to understand past innovation journeys and, on the basis of the insights, enhance the SNM framework. Less work has been done on managerial aspects of the framework, although some of the studies were used in policy arena's to learn from past experiments (e.g. Schot et al., 1996; Van der Laak et al., 2006). So an important challenge for future research is to enhance the managerial aspects of SNM.

This short presentation illustrates that there are many similarities and complementarities between the three approaches. They focus on socio-technical experiments and the development of a more reflexive practice. Central processes are the forming of visions, the composition and alignment of the social networks and learning processes. The main difference is the unit of analysis and the users targeted. Socrobust and Create Acceptance mainly focus on single projects; they are a consultancy tool used to support innovators and project managers with the implementation of R&D and innovation projects. SNM takes the more cumulative level of the niche as a starting point with program managers as the main user (intended). As a consequence, niche development by exchanging experiences between projects is much more important than the result of single projects. Termination of projects and negative results in learning processes still can contribute to the expansion of the niche.

4. Agenda for future practice and theory on long-term energy options

Developments in the Netherlands provide an example of what social scientists can offer to energy research and policy. The Dutch government recognised the need for transitions to sustainability in a variety of societal domains. In particular in the energy domain a lot of activities are going on. Recently a taskforce has identified 26 transition pathways (Taskforce Energietransitie 2006). Although encouraging, the approach is exemplary for the technology push approach: an integral and systemic vision is lacking, the focus is on technological learning and the vested interests are (over)-represented. The need to pay more attention to social aspects is recognised, but not (yet) addressed satisfactorily. Social scientists in particular can have a major impact:

- Social research can contribute to a vision forming practice in which visions on future energy systems are not only technological resource based
- Social research can contribute to learning focuses on not only technological aspects but also other (political, institutional, societal, cultural, environmental etcetera)
- Social research can contribute to the formation of social networks around long term energy options who represent not only the vested interests, with a strong presence of the energy research community, but also creative and relevant outsiders.
- One of the challenges for SNM-researchers is to test the historical analyses in new or ongoing experiments.

- Also, social research faces the theoretical challenge to enhance the theory, including a more comprehensive view on transition paths and on mechanisms behind those paths.
- Combine the fragmented development of tools such as Socrobust, Create and SNM, and develop a core tool with nice to have add-ons tailored for different target groups and units of analysis.
- Enhance the (business and governmental) understanding that innovation trajectories that have been ended are not necessarily failures, in particular not when learning experiences are transferred to other (new) trajectories. Consequently, evaluation and monitoring of innovation trajectories should take place in a longer time frame than the duration of the individual project.
- Yet another challenge that social research faces, is to strengthen its potential evaluation/monitoring and or even intervention role in energy related issues, by eliciting cooperation between hitherto fragmented approaches and analysing their complementarities and possible conflicts.
- Social research can contribute to the discussion on the role of social science in energy research and policy i.e. by an analysis of first movers in the process of including social scientists in energy research and policy, such as is the case in the Netherlands.
- Finally, another issue that social research needs to tackle is translating the ongoing debate in innovation studies and technology- and society studies at large about the normativity of social scientists getting involved in practice and policy through instruments and or procedural facilitation. In other words social scientists also can be used to reinforce the incumbent system.

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